EGG-TMI-7844
September 1987

cy 1

INFORMAL REPORT

SUMMARY OF TMI-2 DATA BASES

Ronne W. Brower

Idaho National Engineering Laboratory

Managed by the U.S. Department of Energy

EG&G Idaho

Work performed under DOE Contract No. DE-AC07-76ID01570

EGG-TMI-7844

SUMMARY OF TMI-2 DATA BASES

Ronne W. Brower

September 1987

EG & G Idaho, Inc.
Idaho Falls, Idaho 83415

Prepared for the
U. S. Department of Energy
Idaho Operations Office
Under DOE Contract No. DE-AC07-76ID01570

CONTENTS

ABSTRACT

This report summarizes seven major data base products produced by the Data Reduction and Qualification Section of the TMI-2 Accident Evaluation Program. The purpose and a brief descriptions of data base structure are presented in the introductory section together with rational involved in selection of data base media.

Major emphasis in the report is placed in more detailed examinations of four personal computer data bases which utilize an INEL developed data base management system, SAGE. Content of each data base is described, the current development status is defined and future activity associated with each dynamic structures is outlined.

SUMMARY OF TMI-2 ACCIDENT DATA BASES

1.0 INTRODUCTION

On March 29, 1979, the Three Mile Island Unit 2 (TMI-2) pressurized water reactor (PWR) was involved in an loss of coolant accident which resulted in significant damage to the reactor core. This event confronted the technical community with a multitude of questions relative to the cause and effects of severe core damage accidents. The U. S. Department of Energy (DOE) has provided funding to The TMI-2 Accident Evaluation Program (AEP) of EG&G Idaho, Inc. to develop a consistent understanding, or scenario, of the accident including reactor thermal-hydraulics, core damage progression and fission product behavior. Analyses required to develop such a scenario are based on data obtained from on-line measurements recorded during the accident, end-state samples taken from the reactor core, reactor core support structures and surrounding environments, and from independent experiments simulating fuel and fission product behavior during severe accident conditions.

Data base structures were developed to provide repositories for the basic data required for TMI-2 evaluations and for the results of analyses. The purpose of this report is to summarize those data base products through description of their content, intended usage, current status and future enhancement. Some of the data base products were intended solely for AEP internal consumption while others, felt to be of general interest to other TMI-2 investigators, were (or will be) distributed externally to the scientific community participating in TMI-2 research. The most significant data base products include:

> TMI-2 Measurement Archives - 170 direct TMI-2 measurements recorded on plant computers or strip charts were selected as being important to the understanding and analysis of the accident. These data were collected, together with supporting documentation (instrument calibrations, circuit diagrams, etc.), digitized (where necessary) and archived on the Idaho National Engineering Laboratory (INEL) Cray XMP/24 Scientific Computing Facility. Core bore drilling data and gamma scans of the

core bore samples were also placed on the INEL main frame computers. Selected portions of these data archives have been downloaded and included as portions of the TMI-2 PC technical data bases described below.

Measurement Description List (MDL) - The TMI-2 Data Integrity Review Committee (DIRC) was organized and given responsibility to evaluate the measurement data, determine their inherent uncertainty and assign a qualification category (with constraining remarks) to each [1]. MDL is an internal personal computer (PC) data base which was used primarily by DIRC to track their progress.

Plant Configuration Data Base - A data base containing plant drawings, descriptions and data necessary for preparation of the input for the initial TMI-2 standard problem which was proposed at the Committee for the Safety of Nuclear Installations (CSNI) conference held in Idaho Falls, Idaho, February 1987. The time period to be covered by the initial problem included the first two phases of the accident: the loss-of-coolant accident (LOCA) period with the reactor coolant system (RCS) pumps on (0 - 100 minutes) and the initial core heatup and degradation period (100 - 174 minutes).

Sequence of Events Data Base (SOE) - A PC data base which contains a compilation of events that occurred within the TMI-2 plant for the period March 28 through April 30, 1979. The records in this data base are primarily textual in nature and focus on operator actions and plant response. [2]

Initial and Boundary Conditions Data Base (ICBC) - This PC data base contains the best available estimates of TMI-2 plant operational parameters during the LOCA transient through core degradation. It contains decimated representations of all archived time series measurements from the TMI-2 plant which were reviewed and were assigned qualification categories by the DIRC. Estimates of vital plant parameters obtained from detailed analyses of plant data are

included (e.g., high pressure injection/makeup flow rates, auxiliary feedwater flow). Calculated fuel burnup data at the time of the accident initiation are also included. [3]

Core Bore Drilling Data Base (CB) - The end-state conditions of the TMI-2 damaged core are described graphically in this PC data base. The diagrams, contour mappings and data functions currently included are associated with analyses of data acquired from the upper debris bed and the core boring operation. [4]

Sample Examinations Data Base (SE) - This PC data base contains physical, metallurgical, chemical and radiochemical analysis results of post accident samples taken from the damaged TMI-2 nuclear power plant. Only data reported and reviewed to this date are currently included; other data will be included as they are released. The results of sample analyses and data processing algorithms will be included if additional data base development resources are made available. [5]

Effort was made during the development of TMI-2 data bases to utilize computer and software systems which best met the purposes of the data bases. The MDL data base was written for IBM PC systems using the Ashton Tate product dBASE III (as were several other miscellaneous data bases used internally). Reports from this data base have been extracted and used in other TMI-2 documents (as tables and appendices).

The Plant Configuration data base was intended to contain preliminary information for use by TMI-2 standard problem participants. It had limited application as a reference in construction of computer models of the TMI-2 primary and secondary systems. It was decided that the most effective way to transmit such information was in hardcopy form as an informal document.

The remaining four scientific data base structures (SOE, ICBC, CB and SE) were built using SAGE, an INEL data base software package. The primary purpose of this data base summary document is to describe the applications and status of these structures.

2.0 TMI-2 DATA BASE MANAGEMENT SYSTEM

2.1 Background

The primary users of TMI-2 technical data base systems were to be engineers and scientists responsible for accident analyses. The data base management system (DBMS) selected had to provide an integrated "information engineered" methodology for the organization, processing, control and retrieval of scientific data consisting of text records, time series functions, and the results of sample or calculational analyses.

Other factors considered in DBMS selection included:

The data base structures should be readily available to researchers at sites other than the INEL;

The working environment should be user friendly with an easy-to-use structure complete with on-line documentation (help messages); and

Full data independence among the physical layout and organization of the data, the logical model (schema) of the data and the applications programs should be achievable. Data base designs should achieve a controlled redundancy in data storage (tradeoffs optimized between non-redundancy and efficient applications usage).

The TMI-2 data base development effort had budget and schedule commitments which were established, of necessity, before the data base development activity was actually begun. This constraint required that maximum use of the experienced personnel involved with scientific data base specification, design and development be utilized.

2.2 Data Base Hardware Requirements

It was decided that the data bases would be built to operate on IBM personal computer systems (PC, XT, AT or PS/2) or 100% compatible facilities since IBM systems were the equipment defined as standard for the INEL. The host PC system must be operated under IBM Disk Operating System Version 2.1 (DOS 2.1) or newer software (Note - Some data base plotting problems have been encountered since the release of DOS 3.3 and corrections incorporated in soon-to-be released versions of TMI-2 data bases). The following additional hardware features are required for operation of the TMI-2 data bases:

a diskette drive, double sided (320/360KB) or high capacity (1.28MB);

a display with color a graphics adapter (CGA) or enhanced graphics adapter (EGA); EGA recommended. Note that use of an IBM EGA also requires that the system have a 16 color IBM memory expansion card (P/N 1501201);

an internal fixed (hard) disk unit (minimum of 20MB);

640KB memory; and

a math coprocessor (8087 for PC and XT; 80287 for AT).

Some data bases generate outputs (e.g. plots, reports) that are hardware dependent. The data bases support those devices that are in common use at INEL. In particular, plotted hardcopy output data requires:

a. an EPSON FX series plotter (or 100% compatible unit), and/or

b. a Hewlett-Packard plotter (Model HP7450, HP7470, HP7475 or HP7550).

The data base software routines for output generation require that PC system hardware be defined in a file (PCSYS.CFG) located within the \DOS directory of the system on which they operate. When a user attempts to perform any output option, this file is interrogated to determine if the user's PC system has an acceptable output device. Appropriate error indications are issued if the operation is not permitted.

2.3 SAGE Data Base Structures and Operations

The TMI-2 scientific data bases use three major software systems; SAGE, Modula-2, and MPG. SAGE, an INEL product, is a scientific oriented development utility with versatile relational data base tools, including a convenient schema and form development package (THOR). Modula-2, an applications language used in connection with the SAGE software, is a state-of-the-art, structured language developed to overcome the shortcomings of PASCAL. MPG is an EG&G plotting package (which employs Media Cybernetics' HALO utilities) built expressly for SAGE personal computer applications.

User interface with the data bases is through a hierarchical system of menus and forms. A typical system structure based on forms is contained in Figure 1. User interaction is accomplished via fill-in-the-blank selections which determine data base operation.

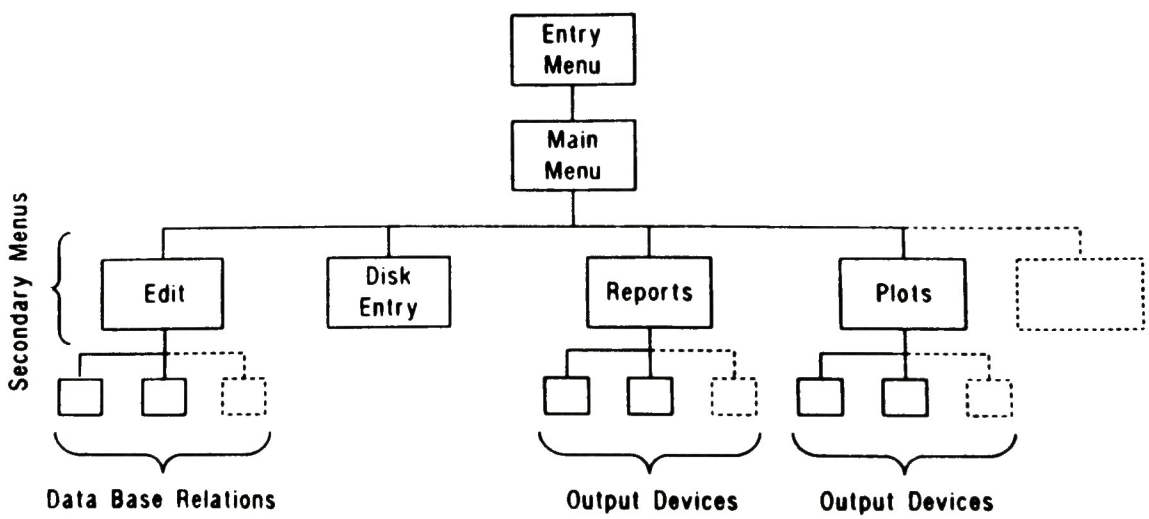

Figure 1. Form Configuration for TMI-2 Data Bases

The input are shown in reverse video on a monochrome display and in a different color on a color monitor. A cursor (blinking dash) is used to identify the current position within the form. Movement between input fields is accomplished by: (1) completely filling in a field, (2) by depressing the <TAB> key that causes a sequential transfer to the next field; (3) by using the backtab keys <Shift/TAB> to move to the previous field; (4) by using the four arrow keys in the numeric pad section of the keyboard; or (5) by selecting the <HOME> key to transfer to the primary (generally first) field. A carriage return <Enter> entry causes the user supplied information to be interpreted by the data base software and the requested operations to be performed.

User entries are processed for legitimate response. When an error is detected (such as an incorrect format or an entry out of range, a bell sounds and a brief error statement is displayed at the bottom of the display screen.

On-line help is available from the various fields of the forms by striking the <ESC> key. This causes a help form to be overlayed on the screen. The help form describes the options available/information to be entered for the field(s) in which the cursor is currently located. An <Enter> is used to return from help messages to the original position within the form (note that when multiple <ESC> key operations are required to complete a user help request, an equivalent number of <Enter> operations are required to return to the form). Some general form options provided by SAGE can be reviewed at any time by depressing the <ALT> and <H> keys simultaneously.

In addition, user reports (see references 2 through 5) are available to assist understanding of the data bases. These documents contain detailed descriptions of the forms with processing examples and results. The data within the data base structures are described in the appendices to these user reports.

2.4 Acquisition of TMI-2 Data Bases

The TMI-2 scientific PC data data bases may be acquired free of charge to agencies connected with DOE sponsored TMI-2 research by written request to:

Manager, Severe Accident Technology Program
EG&G Idaho, Inc.
P. O. Box 1625
Idaho Falls, Idaho, 83415

2.5 Data Base Installation

SAGE data bases are transported on double sided (320/360KB) diskettes containing all necessary data and program files for operation. Those files with extensions of '.DAT', '.BLK' and '.IDX' are the data files. M2.EXE is the Modula-2 executable driver and the '.LOD' files are overlay routines that contain the applications software to operate the data base. Those files with 'HALO' in the filename are for plotting of TMI-2 data.

An installation batch file named INSTALL.BAT on diskette 1 of each data base set is used to install the files on the user's fixed disk system. To perform this installation, the user inserts diskette 1 into the diskette drive and types the command 'A:INSTALL'. INSTALL, will create a data base subdirectory on the PC fixed drive and will copy all files from diskette 1 onto the disk. Following the transfer from diskette 1, the user will be instructed to remove it and insert the second diskette for transfer of its contents to the hard disk. A second subdirectory, \HALO, will be created containing the plotting routines.

Data bases are designed to operate from a '.BAT' file in the PC batch area and can be executed by typing an appropriate calling command ('ICBC', 'SOE', 'CB', or 'SE') at the PC system prompt. All files (default RPT.RPT or user defined) produced by the TMI-2 data bases will be written to disk in the data base subdirectory (e.g., a sequence of events report would be written into the \SOE subdirectory). It is recommended that the data base calling command (example - 'ICBC - Initial and Boundary Conditions data base') be added to the bootup software menu of the user's PC system.

3.0 DATA BASE DESCRIPTIONS

3.1 Sequence of Events Data Base (SOE)

Data in the SOE data base was extracted from GPU TDR-044 and TDR-261 [6,7], considered to be the most complete of the published sequence of events reports on the TMI-2 accident. Information taken directly from TDR-044, covering the events of the first 20 hour period of the accident on March 28, 1979 includes:

Event (EVT) records - text records of varying length that describe plant response conditions. Attributes of these records include time (with notation of "approximate" depending upon the accuracy of the data source) and encrypted designation of the data source references.

Information available to the operator (OPR) records - text records of varying length that describe information the operators had access to regarding each EVT record (there is a one to one correspondence). Many abbreviations, common to control room operations, are used in operator records; a table of these abbreviations and their meaning is provided.

Plant status (STA) records - records of varying length that summarize the overall conditions existing in the TMI-2 plant at different times throughout the day. The SOE time attributed to these records is that of the preceding event records.

Reference descriptions - a list of reference designations and associated source descriptions. Note that the reference designations have been altered in SOE for better alphanumeric sorting.

Information taken directly from GPU TDR-261, include:

Event (EVT) records - text records that describe operator actions with associated date, time and data source reference.

Daily summaries of major plant events - textual records treated as equivalent to the plant status summaries (STA) within TDR-044. A time of 23:59:59 has been associated with each of these daily records.

Daily plant conditions - data as recorded for (1) selected reactor coolant parameters (system pressure, hot and cold leg temperatures for both loops, pressurizer level and operating primary coolant pumps); (2) the five hottest incore thermocouple readings; (3) steam generator level and status for both loops; and (4) reactor building temperature pressure and hydrogen concentration. Notes associated with these parameters have been incorporated into SOE (example: "Steaming to the main condenser" as a status attribute of steam generator A on 03/30/79).

Additional daily conditions (XCD) - text records of varying length included in TDR-261 as noteworthy plant conditions.

The principal usefulness of SOE is the ability to sort textual records and produce reports based on record type (EVT, OPR or STA). The selection process permits users to specify the records he desires to retrieve based on a time interval, a logical matrix of record descriptors or on character string searches. Time selection is accomplished on the basis of date plus wall clock time in (format = MM/DD/YY + hh:mm:ss) or as time relative to the start of the accident (04:00:37 on 03/30/79) in days, hours, minutes or seconds.

Descriptive indices to each of the sequence of events records were defined based on elements (measurement, pump, valve, etc.) or information content within the text records. A component, subsystem, system triplet model was developed to relate these descriptors. In addition, a keyword index system was provided to relate records that might be significant to some special purpose (example - some records have comments included based upon current analyses of the accident and are linked to the keyword 'MODIFIED'). EVT and OPR text records may be retrieved using a three by

four logical matrix of descriptors. The matrix consists of the union (logical OR) of up to three intersections (logical AND) of four index descriptors.

Additionally, records may be retrieved via specification of of arbitrary character strings. The union of two strings (40-character maximum), which may each be 'AND'ed with a single descriptor, can be used.

In addition, supplementary report material may be generated for the records retrieved which lists the plant components mentioned and their descriptions, the record reference abbreviations and their meanings or both the components plus references. A table of operator record abbreviations and interpretations is available as are tables of the system, subsystem, component and keyword indexes.

Fixed reports are available which list plant primary coolant system conditions, core exit thermocouple conditions and miscellaneous plant conditions during the period from day 2 - 31 following the event. Textual note records pertaining to these data may be optionally generated. A time interval specification (in days) is permitted with these reports which may be output in English or metric units.

3.2 Initial and Boundary Conditions Data Base (ICBC)

Initial conditions consist of plant operational parameters, status of operating systems and burnup condition of the nuclear fuel at accident initiation. Phenomena that occurred in the pressurizer, mass transfers within the primary system, reactor coolant pump operations, and steam generator performance constitute the reported boundary conditions data. All data in the ICBC have been reviewed by AEP's DIRC, which assigned qualification categories and has approved uncertainty estimates developed through analyses of plant data. The procedures followed by DIRC have been

written into a methodology based largely on methods proposed by Abernathy [1]. Published analyses of plant ICBC data are contained in other referenced reports. By convention, all data within ICBC are stored in units commonly used in the TMI-2 plant and existing literature (predominately English). Metric units are also available to users.

The ICBC data base has four principal data storage areas:

COND - Contains plant conditions data by type, value, associated time, description, uncertainty, physical unit code, and applicable note reference(s). This area contains time series boundary conditions stored in block form within the data base. These functions have attributes that include measurement identification, descriptions, uncertainty estimates, data qualification categories and statements.

TIMSER - Contains all time series functions that have been reviewed by DIRC and assigned to a qualification category.

USER An area provided for data base users to enter their own time series functions into ICBC. This area is also used as a repository for functions which have been transformed using the data manipulation capabilities within the data base.

Fuel Burnup - Contains original enrichment and location of all fuel assemblies within the TMI-2 core, the total burnup in each assembly at seven axial elevations within the core and reference(s) to applicable notes.

ICBC contains an internal plotting capability for time series functions from the TIMSER or USER areas as well as certain piecewise discontinuous functions, such as primary coolant pump operation, from the COND area. Selectable plot formats include single variable time series plots with linear or semi-log ordinates; multiple (up to five) plots of time series functions of the same physical type on a common set of X, Y axes; and, plots of two dissimilar time series functions with individual ordinates on a common time axis. Data may be output in English or metric units on the PC system monitor, on an Epson FX series printer or on some Hewlett-Packard plotters.

ICBC assists the user in selecting time series data he wishes to plot. The user may obtain time series function lists from the data base relations by defining the logical intersection (AND function) among (1) the function type (e.g., pressure, temperature), (2) reactor system (e.g., pressurizer, reactor coolant), (3) the leading characters of time series function names (example = RC-15A*, where * is a wild card character), or (4) data base area selection (<C>OND, <T>IMSER, <U>SER or <A>LL (the default). Identifications and descriptions are then retrieved and displayed (seven at a time) on the PC monitor. The retrieved information is sent to a report RPT.RPT in the \ICBC subdirectory of the PC system where it may be disposed of as the user desires (note that RPT.RPT is used in many data base output situations and is written over frequently).

The user may page forward and backward through the function list and select data to be plotted by marking the functions on the the PC forms. Up to 10 functions may be selected for plotting at one time; they must be numbered 1 - 10 if the function list was generated from the single plot menus, from 1 - 5 in pairs if the list was created from the two plot menu, or in two groups, 1 or 2 for plotting multiple functions.

Users are given further options to title plots and to label the ordinate and abscissa axes. Parts of data functions (windows) may be selected by specification of minimum and maximum axis ranges. Completion of these data parameters and execution of a display command causes the selected function(s) to be accessed on the disk and the time and amplitude ranges, number of points, and the unit code to be displayed at the bottom of the screen.

ICBC has the feature available to create listings of time series functions. These lists may be written as disk files; a useful feature to extract time series data for processing in some other software package. Decimation is provided by selection of every nth point or by using an iterative minimum/maximum file compaction algorithm in which the least and greatest of each consecutive three points are chosen until the number of points in the file is less than a user defined number in the range 1 - 1000 (default of 1000 points).

The ICBC data base provides an area (USER) in which a user can enter time series functions, such as the results of calculations, for comparison with similar functions contained within the data base. The user must first organize the data in an ASCII disk file using some PC text editing utility. ICBC contains a data entry form for describing data so that it can be loaded into the USER area. Upon completion of the data entry process, the user can specify a function name, description, physical unit code and other descriptors consistent with the policies of assigning function attributes to TIMSER data.

Time series data functions from the COND, TIMSER and USER areas can be manipulated by any user. Simple mathematical operators (add, subtract, multiply or divide) may transform a selected function using a specified constant or another selected function. (1) Functions may be raised to a power; (2) the common or natural logarithm of functions may be obtained. Manipulations include (3) taking the absolute value of a function, (4) shifting the function time base by specification of a value (remember that the ICBC time values are assumed to be in minutes), (5) taking the square root of a function, or (6) integration or differentiation of a function. Functions within the USER area of ICBC may be deleted from the data manipulation form. The results of data manipulations are written into the USER relation. They must be identified in the ICBC with a unique identification in the new function field.

Manipulations are performed by identification of the functions involved and selection of the transformation by associated number command on the monitor form provided. For convenience, a function selection option is provided which is much like the one used in ICBC plotting; that is, subsets of time series functions can be located and presented to the user on forms containing identifications and descriptions and the functions to be transformed may be selected from these lists.

3.3 Core Bore Drilling Data Base (CB)

The Core Drilling data base (CB) contains information regarding the end state of the damaged TMI-2 core as revealed through physical examinations and analyses of core samples. The information is presented largely in the form of contour maps, core diagrams and functions which are the results of analyses; CB does not contain processing capability.

CB contains processed drilling parameters and gross gamma scan results from the core bore sampling program conducted during July and August 1986. Drilling data from the core bore drilling machine (see reference 1) for the 10 core bore holes (D04, D08, G08, G12, K06, K09, N05, N12, 007 AND 009) and the reference calibration hole were placed on the INEL main frame computers where the data with a time base were converted to distance functions. A penetration rate function (in./sec) was then calculated by taking the distance between points and dividing by the time increment; an energy rate function (ft-lb/in) was produced by integrating the product of drill speed (RPM) and torque (ft-lb) over time increments and dividing by the distance the drill bit moved in that time. Functions were then modified to remove those data points where the distance reversed itself when the drill bit was stopped, withdrawn and then the drilling operation continued and were smoothed by computing a 20 point block average.

The gross gamma scan data were generated at INEL in the Test Area North hot shop facility using a gross gamma ray spectrometer. These data were recorded as a continuous analog signal on a strip chart device and later digitized by the TMI Accident Evaluation Program staff (see reference 2).

Summary diagrams illustrating the principal features of each of the core bores are included. From the core bore diagrams, end-state core configuration estimates were mapped at various cross sections throughout the

core. These sets of diagrams may be viewed singly or as sequences. Textual notations of significant core features are available as supplementary reports to these diagrams.

Contour maps of the core depicting the upper debris top surface contour, the upper surface of the previously molten core region, etc. are available from geological analyses of core data. Miscellaneous other diagrams which promote understanding of the end-state of the TMI-2 accident are included in CB.

3.4 Sample Examinations Data Base (SE)

The Sample Examinations data base (SE) contains physical, metallurgical, chemical and radiochemical analysis results of post accident samples taken from the damaged TMI-2 nuclear power plant. Only the data which have been reported and reviewed are included, thus the data base is not complete at this time. The current contents include:

Physical, metallurgical, chemical and radiochemical results of examinations of 11 upper debris bed grab samples collected at two core locations (H8 and E9) during September-October 1983 and March 1984 [8].

Physical, metallurgical, chemical and radiochemical results of examinations of lower plenum debris collected through inspection ports 7 and 11 in July 1985 [9].

Photo indices of lower plenum inspection support grab samples and core bore samples.

Data have been arbitrarily identified with prefix letters which identify them according to the sample set to which they belong. For example, core grab samples from the upper debris bed have been designated

with the letters 'GB' and the core location from which they were collected; thus GBH0856 identifies the grab sample taken from the H08 grid location 56 cm. from the surface. Similarly, grab samples taken from the lower plenum inspection ports have been identified with the prefix 'LPIP', the port number and the sample number; thus, LPIP1104 identifies sample 4 taken from inspection port 11. Core bore samples are identified with a 'CB' prefix and the core grid identifier from which they were collected; thus CBD04 is the core bore from location D4. Sample IDs are further tagged with sub- and tertiary-identifiers to distinguish specific portions which have undergone analysis.

As acquisition and analysis of other samples are completed they will be added to the data base files. These additions will continue through fiscal year 1988. It is intended to incorporate in SE sample, analysis and system information from samples acquired throughout the TMI-2 system in the 1979 - 1983 time frame which are determined to be meaningful in light of current fission product analyses. Algorithms which process the SE data to provide results summaries will be added to the data base consistent with the available resources.

REFERENCES

1. J. L. Anderson, R. D. McCormick, D. W. Golden, TMI-2 Data Summary Report, EG&G Idaho, Inc., Informal Report EGG-TMI-7843, September 1987.

2. R. W. Brower, L. J. Fackrell, M. L. Harris, TMI-2 Sequence of Events Data Base, Version 2.0, EG&G Idaho, Inc., Informal Report GEND-INF-079, February, 1987.

3. R. W. Brower, L. J. Fackrell, M. L. Harris, TMI-2 Initial and Boundary Conditions Data Base, Version 3.1, EG&G Idaho, Inc., Informal Report GEND-INF-078, November, 1987.

4. R. W. Brower, L. J. Fackrell, M. L. Harris, TMI-2 Core Bore Drilling Data Base, Version 1.1, EG&G Idaho, Inc., Informal Report GEND-INF-076, October, 1987.

5. R. W. Brower, L. J. Fackrell, C. L. Olaveson, TMI-2 Sample Examinations Data Base, Version 1.0, EG&G Idaho, Inc., Informal Report GEND-INF-085, August, 1987.

6. T. L. VanWitbeck and J. Putnam, Annotated Sequence of Events, March 28, 1979, GPU Nuclear, Technical Data Report TDR-044, March 1981.

7. Robert Smith, Annotated Sequence of Events - March 29, 1979 through April 30, 1979, GPU Services, Technical Data Report TDR-261, May 1981.

8. D. W. Akers, et. al., Draft Report: TMI-2 Core Debris Grab Samples - Examination and Analysis, EG&G Idaho, Inc., EGG-TMI-6853, Parts 1 and 2, July 1985.

9. Charles S. Olsen, et. al., Examination of Debris from the Lower Reactor Head of the TMI-2 Reactor (Draft), EG&G Idaho, Inc., EGG-TMI-7573, April 1987.